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Update: On the synthesis of quantum Hall array resistance standards (2015 Metrologia 52 31) / Ortolano, Massimo; Callegaro, Luca. - In: METROLOGIA. - ISSN 0026-1394. - 56:2(2019), p. 022101. [10.1088/1681-7575/ab065f]

Availability:

This version is available at: 11583/2726851 since: 2019-03-01T11:54:29Z

Publisher:

IOP

Published

DOI:10.1088/1681-7575/ab065f

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Update: On the synthesis of quantum Hall array resistance standards (2015 *Metrologia* 52 31)

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Abstract. This work provides an update, according to the revised SI, to table 1 of M. Ortolano et al., “On the synthesis of quantum Hall array resistance standards”, *Metrologia*, 52, p. 31–39, 2015. The table reports fractions of the quantized Hall resistance approximating decadic values and the associated deviations. In several cases, the deviations have become smaller in the revised SI.

Submitted to: *Metrologia*

Quantum Hall array resistance standards (QHARS) are integrated circuits of interconnected quantum Hall elements. They are designed to provide a quantized resistance R approximating a nominal resistance value R_0 of practical interest, typically a decadic value (e.g., 10 k Ω). R is a fraction $R = (p/q)R_H$ of the quantized Hall resistance R_H of the individual elements composing the QHARS, and p and q are integers. The quantized Hall resistance is a submultiple of the von Klitzing constant, $R_H = R_K/i$, i being a small integer (here we assume $i = 2$, as is usually the case).

In [1], we proposed an algorithm that, given the target resistance R_0 , allows to calculate the fractions p/q of interest, and to design the corresponding QHARS networks. Table 1 of [1] provides several examples of practical interest for the decadic values 100 Ω , 1 k Ω , 10 k Ω , 100 k Ω and 1 M Ω . The approximations reported in [1], and the corresponding deviations of R from R_0 , were calculated by assuming the conventional value of the von Klitzing constant $R_{K-90} = 25\,812.807\,\Omega$ [2, Appendix 1].

The redefinition of the International System of Units [3] fixes the value of the von Klitzing constant R_K according to the last CODATA 2017 recommendation [4, table 3], $R_K = h/e^2 = 25\,812.807\,459\,304\,5\,\Omega$ (calculated to 15 significant figures, as given in [5]). This value relatively differs from R_{K-90} by 1.78×10^{-8} .

The present work provides in table 1 below an update to table 1 of [1] according to the revised SI. A few sign errors in the original δ_{90} values have also been corrected. It is of interest that several approximations provide a lower relative error in the revised SI.

The Mathematica [6] notebook implementing the search of approximating fractions as described in [1] and employed to generate table 1 is available at <https://github.com/INRIMQuantumElectricalMetrology/SternBrocot>.

References

- [1] M. Ortolano, M. Abrate, and L. Callegaro, “On the synthesis of quantum Hall array resistance standards,” *Metrologia*, vol. 52, p. 31, 2015. [Online]. Available: <https://doi.org/10.1088/0026-1394/52/1/31>
- [2] Bureau International des Poids et Mesures, “The International System of Units (SI),” 2006, 8th edition. [Online]. Available: www.bipm.org
- [3] —, “Draft of the 9th SI brochure,” Feb. 2018. [Online]. Available: www.bipm.org

Table 1. Summary of the cases analyzed in [1]: $\rho_{0-90} = R_0/R_{H-90}$ is the target resistance value normalized to the Hall resistance $R_{H-90} = R_{K-90}/2$; $\rho_0 = R_0/R_H$ is the target resistance value normalized to the Hall resistance $R_H = R_K/2$, calculated with the revised value of R_K ; $\rho = p/q$ is a rational approximation for ρ_0 and ρ_{0-90} ; $\delta_{90} = (\rho - \rho_{0-90})/\rho_{0-90}$ and $\delta = (\rho - \rho_0)/\rho_0$ are the relative errors of the approximation. Values are rounded at the 10^{-10} level. Table 1 of [1] reported δ_{90} .

ρ	δ_{90}	δ
$R_0 = 100\,\Omega$		
47/6066	$+1.5900 \times 10^{-6}$	$+1.6078 \times 10^{-6}$
78/10067	-5.235×10^{-7}	-5.057×10^{-7}
125/16133	$+2.712 \times 10^{-7}$	$+2.890 \times 10^{-7}$
203/26200	-3.42×10^{-8}	-1.64×10^{-8}
$R_0 = 1\,\text{k}\Omega$		
203/2620	-3.42×10^{-8}	-1.64×10^{-8}
235/3033	$+1.5900 \times 10^{-6}$	$+1.6078 \times 10^{-6}$
$R_0 = 10\,\text{k}\Omega$		
203/262	-3.42×10^{-8}	-1.64×10^{-8}
$R_0 = 100\,\text{k}\Omega$		
1015/131	-3.42×10^{-8}	-1.64×10^{-8}
$R_0 = 1\,\text{M}\Omega$		
4029/52	-1.9288×10^{-6}	-1.9110×10^{-6}
6121/79	$+1.2130 \times 10^{-6}$	$+1.2307 \times 10^{-6}$
10150/131	-3.42×10^{-8}	-1.64×10^{-8}

- [4] D. B. Newell, F. Cabiati, J. Fischer, K. Fujii, S. G. Karshenboim, H. S. Margolis, E. de Mirandés, P. J. Mohr, F. Nez, K. Pachucki, T. J. Quinn, B. N. Taylor, M. Wang, B. M. Wood, and Z. Zhang, “The CODATA 2017 values of h , e , k , and N_A for the revision of the SI,” *Metrologia*, vol. 55, p. L13, 2018. [Online]. Available: <http://stacks.iop.org/0026-1394/55/i=1/a=L13>
- [5] Consultative Committee for Electricity and Magnetism, “*Mise en pratique* for the definition of the ampere and other electric units in the SI,” Dec. 2017, draft for Appendix 2 of the SI Brochure for the “Revised SI.” [Online]. Available: www.bipm.org
- [6] Wolfram, “Mathematica 11.” [Online]. Available: <http://www.wolfram.com/mathematica/>